Outline of Tasks to Accomplish Development of a Wildland Fire Susceptibility Process

The following outline summarizes the Tasks and data needs to accomplish the calculation the Wildland Fire Susceptibility Index (WFSI) as completed in the Lake Tahoe Basin Fire Risk Assessment project. In addition, a description of how the WFSI could be used with a Values of Concern Index (Fire Effects Index) is provided. This wildland fire risk assessment process is outlined by Task as follows:

- Task 1 - Assess the potential for wildland fire occurrences.
- Task 2 - Assess fire behavior and resultant fire sizes.
- Task 3 - Determine the susceptibility of the study area to wildland fires by integrating wildland fire occurrence and fire behavior/fire growth (WFSI).
- Task 4 - Develop Values of Concern areas and the Concern Rating Index (CRI)
- Task 5 - Develop the the final product of the process which is the Wildland Fire Risk Index (WFRI) as a combination of the Wildland Fire Susceptibility Index and the Concern Rating Index (CRI).
- Task 6 - Integrate the role of fire in ecosystem dynamics into the evaluation process
- Task 7 - Identify Strategic Planning Areas

The following summary provides detail of each Task via sub-task processes.

Task 0 Start-up Meeting
The purpose of the meeting outline the project goals and objectives. In addition, a draft outline of the deliverable should be developed.

Task 1 Assess the potential for wildland fire occurrences

The WFSI is calculated using an estimate of the probability of each acre or cell in the GIS data base igniting. To do this, the planning area is stratified into area with uniform fire occurrence rates called Fire Occurrence Areas (FOA).

<u>Task 1- 1 Obtain fire occurrence information from all agencies</u>
Determine the period of time that fire occurrence information is needed. A period of from 10 to 20 years is most likely to provide a statistically valid data set. Obtain in digital form fire occurrence data for the time period.

Task 1- 2 Verify location of each wildland fire

Verify as accurately as possible the location of each ignition. Corrections may need to be made if there was an error in the initial recording of the ignition location or if the conversion of the initial fire location is not accurate due to the conversion from a legal Twn/Rge/Sec format to a latitude/longitude or UTM format. This task should involve the development of maps of ignitions to aid in the locating of suspect "out of bounds" fires.

Task 1-3 Assign a Ignition Density Value to each Cell

Densities of fire occurrence (FOAs) are developed using ARC/INFO grid and the Density function. A grid of 30 meter x 30 meter cells should be laid over the ignition sites and densities calculated with a defined radius (2,200 meter suggested) around each cell.

Task 1- 4a Develop FOAs

Discrete FOAs were defined as a series of cells with ignition density values. This ordination is done to group cells into a defined number of areas. The probability of an acre igniting for each acre in an FOA is determined by dividing the actual number of ignitions in the FOA by the time frame for the ignition data and expressed in fires per 1,000 acres per year. The stratifying of the cells into FOA's from the density values can be gone using percentiles or by using defined equidistant breaks of the density values. Previous assessments have used between 5 and 10 FOA categories. In the development of the FOA categories, favor initially a number that will stratify the FOA rate into finite levels to which do not mask detail.

An example of FOA categories is given the table that follows:

Example Fire Occurrence Area Descriptions for an Area

	FOA 1	FOA 2	FOA 3	FOA 4	FOA 5	FOA 6	FOA 7	Totals
Acres	541,578	56,746	41,482	9,446	7,658	9,968	608	667,486
Fires	1,293	497	604	173	200	370	36	3,193
Years	27	27	27	27	27	27	27	27
Fires/Yr	42.89	18.41	23.11	6.41	7.41	13.70	1.33	118.26
Fires/1000 Ac/Yr	0.0884	0.3244	0.5571	0.6783	0.9673	1.3748	2.1930	0.1776

Task 1- 4b Prepare FOA Map

Prepare the FOA map both with each ignition location plotted and also one without ignitions plotted.

Task 1- 4c Review of FOAs and Make Adjustments

The draft FOA map should be review for adequacy and accuracy.

Task 1- 4d Prepare Final FOAs

Make corrections are necessary and develop the final FOAs and maps.

Task 2 Assess Fire Behavior and Resultant Fire Sizes.

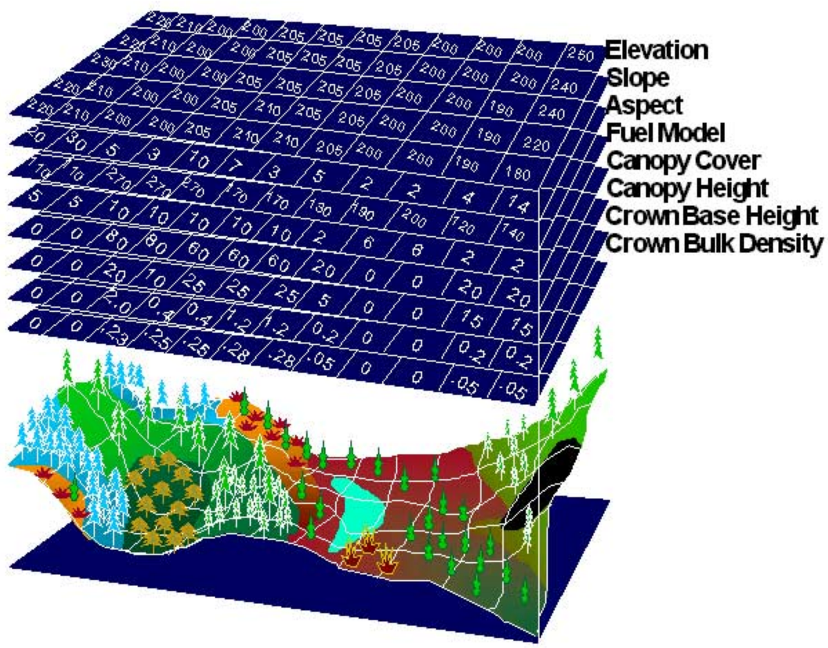
Fire behavior assessment will require the gathering of data on fuels, weather and topography. The fuels and topography data will need to me gathered and mapped spatially. It is recommended these be mapped to a 30 meter x 30 meter resolution. The FlamMap program is the tool that will be used together with weather information to assigned potential fire behavior/fire growth values to each cell in the planning area. The FlamMap program requires input of five data layers: slope, aspect, elevation, canopy cover and Fire Behavior Prediction System (FBPS) fuel model. Optional data layers include stand height, canopy base height and canopy bulk density.

Description of FlamMap

FlamMap is a personal computer program that calculates fire behavior and environmental variables across a landscape using GIS data inputs for terrain and fuels. The purpose of FlamMap is to generate fire behavior data that are comparable across the landscape for a given set of weather and/or fuel moisture data inputs. FlamMap is based on the GIS data themes and algorithms used in FARSITE (Fire Area Simulator) as described by Finney (1998). GIS data are required for 8 data themes:

Required Themes
- Elevation
- Slope
- Aspect
- Surface fuel model
- Canopy Cover

Optional Themes
- Stand Height
- Crown Base Height
- Crown Bulk Density



Fire behavior variables estimated by FlamMap are fire spread rate and intensity, fire state (surface, passive crown, or active crown fire), and fuel moisture. FlamMap calculates the instantaneous behavior of a fire occurring in each at each 30x30 meter cell across the landscape in the entire study area under pre-selected weather conditions. Fire behavior is described independently for each individual cell. It does not account for contagious processes that may affect fire behavior in an adjacent cell.

The potential fire behavior/fire growth values for each cell will be developed based on four percentile weather categories. The resultant fire size projections will be determined by using relationships developed correlating final fire sizes with fire spread rates.

<u>Task 2-1 Obtain GIS Data Layers</u>
As a minimum, the initial data layers needed include DEMs or slope, aspect and elevation. In addition, a cover type and/or potential vegetation map is needed. Additional data layers that would show disturbance are also valuable. Other physiographic layers showing river, roads, etc. will be needed,

<u>Task 2-2 Assign Changes to Cover Types</u>
Makes changes to the cover type map to account for changes since the initial data layers were constructed.

<u>Task 2-3 Develop GIS Layers for Slope, Aspect and Elevation</u>
These data layers a developed for DEM information.

<u>Task 2-4 Develop the Canopy Cover Layer</u>
Use existing GIS data layers.

<u>Task 2-5a Develop the Draft FBPS Fuel Model Layer</u>
Use correlations between existing GIS data layers such as cover type, slope, aspect, elevation, and canopy cover to assign fuel model to develop a cross-walk table. There may be a need to develop some custom FBPS fuel models in this step.

<u>Task 2-5b Field Verify FBPS Fuel Model Layer</u>
The draft fuel model map should be review for adequacy and accuracy.

<u>Task 2-5c Make Changes to FBPS Fuel Model Layer</u>
Make changes based on feedback.

<u>Task 2-5d Develop the Final FBPS Fuel Model Layer</u>
Makes changes to the cross-walk table developed and produce a new map.

<u>Task 2-6a (Optional) Develop the Stand Height, Canopy Base Height and Canopy Bulk Density Layers</u>
Use existing GIS data layers as much as possible to developed these data layers. Tree structural stage is a critical input here. Processes have been developed at the Rocky Mountain Fire Lab in Missoula (Bob Keane, 406-329-4846, bkeane/rmrs_missoula@fs.fed.us).

Task 2-6b (Optional) Field Verify Stand Height, Canopy Base Height and Canopy Bulk Density Layers
The draft data layer maps should be review for adequacy and accuracy.

Task 2-6c (Optional) Make Changes to Stand Height, Canopy Base Height and Canopy Bulk Density Layers
Make changes based on feedback.

Task 2-6d (Optional) Develop the Final Stand Height, Canopy Base Height and Canopy Bulk Density Layers
Use correlations and produce final data layers.

Task 2-7 Develop Weather Influence Areas and Weather Data for These Areas
For the planning area, develop weather influence zones and gather weather observations from weather stations.

Task 2-7a Develop Weather Influence Zones in Consultation with Fire Weather Meteorologists
Most likely, these areas exist for fire danger rating and or smoke management forecasting. Use as much of existing structure as possible. Assign a weather station to each weather influence zone. If more than one weather influence zone is assigned, the weather influence zones will need to be digitized.

Task 2-7b Assign Each Cell to a Weather Influenced Zone
GIS task

Task 2-7b Gather Weather Data and Screen Weather Data for Errors
Gather if possible 20 years of weather data from weather stations. Use appropriate software to find days where erroneous data exists and make adjustments/deletions accordingly.

Task 2-7c Develop Percentile Weather for each Weather Influence Zone
Use the FireFamilyPlus software to develop percentile weather for 4 categories: Low, Moderate, High and Extreme. Develop the appropriate NFDRS fuel model, slope class, climate class, and herbaceous vegetation combination for the weather influence zone. Use the Spread Component to do this task. The initial breaks are as follows:

- Low 0-14%ile
- Moderate 15-89%ile
- High 90-97%ile
- Extreme 98-100%ile

Task 2-8 Determine the Proportion of Fires That Occur By Percentile Weather Category
Using the NFDRS fuel model, slope class, climate class, and herbaceous vegetation combination for the weather influence zones, assign to each historic fire the Spread Component for the day the fire ignited. Use thus information to determine the proportion of fires that occur by percentile weather category.

Task 2-9 Develop Fire Behavior Layer
Use FlamMap with percentile weather to calculate rate-of-spread in each cell. Note that many other outputs are available from FlamMap but the rate-of-spread is needed here to obtain the resultant fire size in a later step of the process.

Task 2-10 Develop Relationships Between Rate-of-Spread and Resultant Fire Size
Key to assignment of an expected resultant fire size for a cell is the correlation between rate of spread and the resultant fire size. The resultant fire size is stratified into three categories: contained fire, escaped fires and maximum fire size.

Task 2-10a Relationship for Contained Fires
The elliptical developed by Fons (1946) area model can be used to obtain the area burned. Inputs to the model are rate of spread time to the containment of the fire and mid-flame wind speed. Data from fire planning models (IIAA, etc) can be used to develop a relationship between rate of spread and containment time of the fire. This mathematical relationship can then be used in Fon's equation to obtain a relationship between rate of spread and fire size. This relationship is only valid up to the rate of spread were escaped fire as occurring.

Task 2-10b Relationship for Escaped Fires
To develop the mathematical relationship here, past fires will need to be examined. Data will need to be gathered from escaped fires. Data needed includes the area a fire covers in a defined period of time as well as the spread rate during this time will be gathered. This data can be for the fire as a whole or for initial runs of a escaped fire. The fires to be examined will most likely be recent fires as in general, a query of information from personnel very familiar with each fire will be needed,

Once developed, a multi-variate regression is performed to obtain a mathematical expression that approximates these values. This relationship is used for rates of spread greater than the spread rate limit for contained fires and less than the maximum fire spread rate.

Task 2-10c Maximum Fire size
Due to topographic limitations, there may be a desire to determine a maximum fire size. The threshold rate of spread at which the maximum fire size is attained for all spread rates higher than the threshold value is determined from the mathematical relationship correlating rate of spread and escaped fire size.

Task 3 - Determine the Susceptibility of the Area to Wildland Fires by Integrating Wildland Fire Occurrence and Fire Behavior/Fire Growth (WFSI).
The wildland fire susceptibility analysis integrates the:

- Probability of an acre igniting and
- Wildland fire behavior in terms of an expected fire size.

The process combines the data from the FOAs with fire behavior data developed by FlamMap. This analysis calculated a Wildland Fire Susceptibility Index (WFSI) for each 30x30 meter cell in the study area. Rankings of fire occurrence and fire behavior will form the axes of a matrix where every cell will be assigned a single value that describes all combinations ranging from high occurrence-high fire behavior to low occurrence-low behavior.

Task 3-1 Calculate the WFSI for Each Rate of Spread and FOA Combination.
This current is best done within a spreadsheet program.. The purpose of this task is to create a lookup table for determining the WFSI for any combination of rate of spread and FOA. The lookup is then used with the GIS system to assign the WFSI to each cell for each percentile weather category.

An example portion is shown in the table below. The example assumes the Moderate percentile weather category with in the example as 71% of the fire occurrence within each FOA.

Example of Calculation of Wildland Fire Susceptibility Index For
Two Specific Fire Occurrence Areas (FOA 1 and FOA 2)

Calculation Is For The Moderate Weather Class
The Probability of a Fire in The Weather Category is 0.71 For the Example

Row		FOA 1	FOA 2
1	Total FOA Acres (Excluding water)--->	541,578	56,746
1a	Total Non-Burnable Acres--->	86,304	7,647
1b	Total Burnable Acres--->	455,274	49,099
2	Total Fires in FOA (1970-1998)-->	1,293	497
3	Number of Years for Data-->	27	27
4	Total Fires/Yr in FOA-->	47.89	18.41
5	Total FOA Rate (Fires/1000ac/Yr)-->	0.0884	0.3244
6	No of Fires/Yr in Wx Class in FOA-->	34.00	13.07
7	Rate-of-Spread = 5 Ch/Hr	0.000012	0.000042
8	Rate-of-Spread = 25Ch/Hr	0.010395	0.037048
9	Rate-of-Spread = 45Ch/Hr	0.224048	0.798545

An explanation of each row follows.

Row 1. This is the total number of acres within the FOA not cover by water.

Row 1a. This is the total number of non-burnable acres within the FOA.

Row 1b. This is the total number of burnable acres within the FOA (Row 1 - Row 1a).

Row 2. This is the total number of fires for the time period noted within the FOA.

Row 3. This is the number of years in the time period.

Row 4. This is the Annual Number of Fires within the FOA and is calculated by dividing by Row 2 by Row 3:

Row 4 = Row 2 / Row 3 Equation 5

Row 5. This is the fire occurrence rate in the FOA expressed in fires per 1000 acres per year. It is calculated as follows:

Row 5 = (Row 4 * 1000) / Row 1 Equation 6

Row 6. This is the number of fires per year in the weather class. For this example, the moderate weather class is being used which has a frequency of occurrence of 0.75 but only 71% of the wildland fires historically occur in this weather class. Hence, this row is the product of Row 6 and 0.71:

Row 6 = Row 6 * 0.71 Equation 7

Overview of Rows 7-9. These rows provide the WFSI for each FOA and for a rate-of-spread from FlamMap output.

The WFSI is calculated as follows:

WFSI = (Expected Acres Burned In The FOA) / (Total Burnable Acres in the FOA) Equation 8

The rate-of-spread allows for estimation from Equation 3, Equation 4 or the maximum fire size of the estimation of the final fire size (FFS) for a single ignition that occurs within the cell (Table 15). This FFS is based on the **assumption** that the wildland fire is burning uniformly and continuously in a fuels and topographic situation as is described in the cell. Since there are no contagion effects considered, the calculated value for the WFSI is best viewed as an index that ordinates Wildland Fire Susceptibility based on the probability of wildland fire ignition (FOA) and fire spread potential (FlamMap). If the expected acres burning could be precisely determined, then the WFSI could be viewed as the "probability of an acre burning." For rates-of-spread less than 24 chains per hours, it is a close approximation of the "probability of an acre burning" as the resultant fire size is small.

The "Expected Acres Burned In The FOA" is calculated as follows:

Expected Ac. Burned In The FOA =
FFS * Number of Fires/Year in FOA in Weather Class Equation 9

For this example, assume the values in the follow table for rate of spread versus resultant fire size

(Task 2-10).

Summary of Final Fire Size Based on Rate-of-Spread			
Rate of Spread (ch/hr)	Final Fire Sized Used	Final Fire Size (Acres) Contained Fires	Final Fire Size (Acres) Escaped Fires
5	0.16	0.16	
10	2.50	2.50	
15	12.9	12.9	
20	40.7	40.7	
24	84.0	84.0	
25	170	1573	170
30	463	2265	463
35	1160	3083	1160
40	2623	4027	2623
45	3000	5096	5425
50	3000	6296	10420
55	3000	7614	---
56+	3000	---	---

Row 7. This row provides the WFSI for each FOA and for a rate-of-spread from FlamMap of 5 chains per hour. Since this rate-of-spread is between 1 and 24 chains per hour, Equation 3 (contained fire) is used to estimate the FFS. For FOA 1, this calculation is as follows:

WFSI (FOA 1 & ROS=5 ch/hr) =
(FFS * Number of Fires/Year in FOA in Weather Class) / (Burnable Acres in the FOA)
Equation 10

= (0.16 acres * 34.00 fires/yr) / (455,274 acres in FOA)

= 0.000012

Row 8. This row provides the WFSI for each FOA and for a rate-of-spread from FlamMap of 25 chains per hour. This rate-of-spread is greater than 24 chains per hour; therefore, Equation 4 (escaped fire) is used to estimate the FFS up to a maximum FFS of 3,000 acres. For FOA 1, this calculation is as follows:

WFSI (FOA1& ROS=25 ch/hr) =
(FFS * Number of Fires/Year in FOA in Weather Class) / (Burnable Acres in the FOA)
Equation 10

= (139.18 acres * 34.00 fires/yr) / (455,274 acres in FOA)

= 0.010395

Row 9. This row provides the WFSI for each FOA and for a rate-of-spread from FlamMap of 45 chains per hour. This rate-of-spread is greater than 24 chains per hour and hence Equation 4 (escaped fire) is used to estimate the final fire size (FFS) up to a maximum FFS of 3,000 acres. Using Equation 4, the FFS would be 5,394 acres which is greater than the 3,000 acre maximum FFS assumed. For FOA 1, this calculation is as follows:

WFSI (FOA1& ROS=45 ch/hr) =
(FFS * Number of Fires/Year in FOA in Weather Class) / (Burnable Acres in the FOA)
Equation 10
= (3,000 acres * 34.00 fires/yr) / (455,274 acres in FOA)

= 0.224048 .

Summary of WFSI Calculation
The WFSI value is proportional to the FOA rate (Row 6). The rate in FOA 2 is about 4 times that in FOA 1 and the WFSI values in FOA 2 are about 4 times those in FOA 1. This is a result of the use of the standard "expected value" methodology used to calculate the WFSI. Also note that if a dollar or index "value" were assigned to each cell in a Value of Concern Layer, the product of the WFSI and the index value in the Value of Concern Layer would yield an "expected effects index." That calculation process will follow.

Table 17- Summary for Example of Wildland Fire Susceptibility Index

Calculation Is For The Moderate Weather Class
The Probability of a Fire in The Weather Category is 0.71 For the Example

7	Rate-of-Spread = 5 Ch/Hr	0.000012	0.000042
8	Rate-of-Spread = 25Ch/Hr	0.010039	0.037048
9	Rate-of-Spread = 45Ch/Hr	0.224048	0.798545

Task 3-2 Attribute each Cell in the Area With a WFSI Value for Each Percentile Weather Category.
This is an attributing task.

Task 3-3 Assign a WFSI Value to each Cell By Summing the Percentile Weather WFSI Values
The sum of the percentile weather WFSI values is the WFSI value for the cell.

Task 3-4 Develop WFSI Areas by Constructing a Categories for Grouping of the WFSI values.
Use percentile values or any other defendable method to group the WFSI values into categories. Is allows for intermediate display of areas with similar WFSI values. It in important to not that the raw WFSI values will continue to be used in Task 5 in the development of the Wildland Fire Risk Index (WFRI) which integrates the values of concern effected by a wildland fire with the WFSI.

Task 4 - Develop Values of Concern Areas and the Concern Rating Index (CRI)

Task 4-1   Develop a Map of Values of Concern
Develop a Draft Map of Values of Concern showing areas were there are identified values of concern that could be effected from a wildland fire. These assets could include urban areas, agricultural areas, military bases, major infrastructures, such as electrical-generating and major transmission lines, commercial timber land, and ecologically sensitive areas.

Task 4-2   Verify Values of Concern and Develop Areas of Concern
Work with local personnel to verify the Areas of Concern.

Task 4-3 Develop a Concern Rating Index (CRI)
At a meeting with agency personnel, complete effects assignments with a matrix stratified by fire size and fire intensity. An example is shown below:

Rating of Effects to Obtain CRI		Fire Size		
		0 - 9ac.	10-100 ac.	100+ ac.
Flame Length	0-4'	L=0	M=1	M=1
	4-8'	M=1	M=1	H=2
	8+'	M=1	H=2	H=2

In each cell, the effect on the value of concern is noted as a low, moderate or high effect. The Concern Rating Index for the matrix is the sum of the values. In the example, Concern Rating Index = 11. The CRI runs from 0 to 18. If the agency desires, more levels can be used. The CRI is combined with the Wildland Fire Susceptibility Index to obtain the final Wildland Fire Risk value for an area.

Task 4-4 Develop An Ordination of the of the CRI to Allow for Display of Areas of Similar Concern
Develop an ordinated scale of similar CRI values to allow for development of a CRI map. It is important to remember that this ordination is purely for the purpose of map display. The raw CRI values will be used in Task 5 with the WFSI for each cell on the development of the Wildland Fire Risk Index (WFRI) for each cell in the Data Base.

Task 4-5   Prepare Final Value of Concern Map
Prepare a map of the CRI Areas from Task 4-4.

Task 5 - Develop the Wildland Fire Risk Index (WFRI)

The WFRI is the final product of the and is the combination of the Wildland Fire Susceptibility Index and the Concern Rating Index (CRI).

Task 5-1   Develop a Wildland Fire Risk Index (WFRI) for each cell in the Data Base

The Wildland Fire Risk Index (WFRI) is the combination of the Wildland Fire Susceptibility Index and the Concern Rating Index (CRI) and is the final product of the process. Calculate for each cell the index as follows:

WFRI = WFSI * Concern Rating Index (CRI)

Note that the WFRI is an "expected effects rating" as the WFSI is related to the probability of an acre burning and the CRI is a rating of the effect if a wildland fire burns on the acre.

Task 5-2   Development Wildland Fire Risk Areas (WFRA)

Aggregation of similar Wildland Fire Risk Index (WFRI) values into classes will be done based on the level of resolution determined to be needed. Consider using percentile values or any other defendable method to group the WFRI values into categories.

Task 6 - Integrate the Role of Fire in Ecosystem Dynamics into the Evaluation Process

Fire plays in important role in the development and maintenance of ecosystems.

Task 6-1 Attribute Cells With Natural Fire Return Interval

Attribute each cell in the average fire return interval based on Cover Type and/or Potential Vegetation Type.

Task 6-2 Attribute Cells With Year of Last Disturbance By Fire

Use historic area burned maps from wildland fire and prescribed fires to attribute each cell with the last year of fire disturbance.

Task 6-3 Calculate the Number of Missed Fire Return Intervals

Calculate the number of missed fire return cycles as follows;

Number of Missed Fire Return Intervals = (Years Since Last Fire) / (Average Fire Return Interval)

Attribute each cell with this value.

Task 7. Identify Strategic Planning Areas

Integrate the Wildland Fire Risk Areas (WFRA) with the Number of Missed Fire Return Intervals to prioritize areas that should be evaluated of fuels modification.